WATERTOWN ARSENAL LABORATORY

MEMORANDUM REPORT

NO. WAL 710/653

Resistance of Various Samples of "Fiberglas" to Perforation by Fragment-Simulating Projectiles

BY

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DATE 10 June 1944

WATERTOWN ARSENAL
WATERTOWN, MASS.

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Second Partial Report on Problem B-8.9

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1. As part of a program of development of improved body armor components, requested by the Office, Chief of Ordnance[1], and in response to a specific directive from his office[2], several types of Fiberglas, furnished by the Owens-Corning Fiberglas Corporation and varying in weave, weight and texture, have been tested ballistically at this arsenal.

2. The resistance of these samples to perforation by cal. .45 (steel-jacketed) ball projectiles and by cal. .22 fragment-simulating projectiles[3] seems to reflect the characteristics of the yarn and the closeness of their texture, since those showing greatest resistance were closely woven and made of fine-fibred, multi-stranded, high-twist yarn while those affording lowest resistance were less closely woven and made of yarn with coarser fibres and a lower number of strands. The resistance of the best sample to perforation by cal. .45 ball projectiles compares favorably with that of an equivalent weight of 17½ ounce nylon duck, which has exhibited the greatest resistance of any fabric tested here, but under impact of the cal. .22 fragment-simulating projectile, G-2, it was considerably inferior. However, the resistance of Hadfield manganese steel of equal weight is much greater than either of these fabrics.

3. The weights of the various samples were determined at this arsenal and on the basis of these figures (which varied somewhat from those reported by the supplier) sufficient numbers of plies 12"x12" were assembled to reproduce the weight of a steel sample of equal area, but .044" thick. These assembled pieces were then sewed together with a row of stitching about an inch from the edges of the assembly.

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1. O.O. 422.3/71(c) - Wtn 470.5/7443(c), dated 23 September 1943.
2. O.O. 400.112/6902(r) - Wtn 400.112/3097(r), dated 29 April 1944.
3. WAL Memorandum Report No. 762/253, Development of a Projectile, to Be Used in Testing Body Armor, to Simulate Fragments of a 20 mm. H.E. Projectile, dated 7 January 1944.

These assemblies were then drawn taut across the face of wooden ballistic frames and clamped rigidly thereto. These ballistic frames are so constructed as to allow an area 8"x8" to remain unsupported from the rear. Into the faces of these areas there were then directed impacts of cal. .45 (steel-jacketed) projectiles and of cal. .22 fragment-simulating projectiles. The results of these firings are summarized in Table I.

4. Under impact of the cal. .45 ball projectile the resistance of the two best samples of this material (732 feet-per-second and 738 feet-per-second) compares favorably with that of an equal weight of 17½ ounce nylon duck (750 feet-per-second)[4], but both are considerably inferior to that of an equal weight of Hadfield manganese steel (940 feet-per-second).

5. Under impact of the cal. .22 fragment-simulator, G-2, however, the resistance of even the best of these samples (1188 feet-per-second) is much inferior to that of the nylon duck (1360 feet-per-second) which in turn falls far short of that of Hadfield manganese steel (1660 feet-per-second).

6. Table II recites the physical characteristics of the samples as determined by the supplier. Some slight variance between the weights determined by the supplier and those determined at this arsenal exists, but in no case was there a serious discrepancy.

7. In Table III the correlation between the resistance of the various samples and their yarn and texture characteristics is shown. The various samples have been listed in ascending order of their resistance to perforation by each type projectile. The number of ends per inch is a measure of the closeness of texture, higher values being indicative of closer weaves. The first number in the recital of yarn characteristics is a measure of the fineness of the basic fibre, higher values indicating finer fibres. (The number used is the number of 100 yards lengths of fibre per pound.) The second, dual number indicates the manner in which the yarn is stranded. Its exact interpretation is somewhat complex and has no legitimate place in this report, but suffice it to say that the larger both of these numbers are the greater number of strands are contained in the final yarn. The third number followed by the letters T. P. I. indicates the number of twists per inch of yarn.

8. The most striking aspect of this table is the general inferiority of those samples having coarser fibres (#225). Next, where the fineness of the fibres is identical, an increase in resistance seems to accompany an increase in the number of strands employed. Finally, where both these attributes are constant an increase in the proximity of weaving, as indicated by the number of ends per inch, seems to increase resistance. These are of course exceptions to this general trend, but in view of the many variables involved, some of which are not determinable, these general observations are considered reasonable and valid.

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4. WAL Memorandum Report No. 710/616(c), Resistance of Various Layers of 17½ Ounce Nylon to Several Types of Small Arms Projectiles, 21 April 1944.

9. While the inferiority of this material to nylon duck, in resistance to perforation by the cal. .22 projectile, is not encouraging, there may nevertheless be some feasibility in further development work in view of the possible use of all-fabric armor suiting. If such development work is undertaken the trends apparent in this study should be given serious consideration.

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Table I

Summary of Ballistic Tests Conducted at Watertown Arsenal on Various Samples of "Fiberglas" Submitted by Owens-Corning Fiberglas Corporation

Sample	No. of Plies	Equivalent Steel Gauge	Ballistic Limit (F/S) Cal. .45[1]	Ballistic Limit (F/S) G-2[2]
ECC-112	107	.044"	698	1036
ECC-113	96	.044"	623	1101
ECC-115	94	.044"	588	1030
ECC-116	75	.044"	698	10[illegible]2
ECC-117	79	.044"	671	974
ECC-127	38	.044"	647	108[illegible]2
ECC-128	43	.044"	593	10[illegible]
ECC-138	32	.044"	694	11[illegible]4
ECC-138a	32	.044"	738	11[illegible]3
ECC-161	18	.044"	732	118[illegible]3
ECC-162	19	.044"	618	9[illegible]5
X-1549	14	.044"	669	10[illegible]2
X-1581	39	.044"	549	9[illegible]3
For Comparison:				
17½ Ounce Nylon Duck	12	.044"	750	1[illegible]
Hadfield manganese steel (Average)		.044"	940	1660

[1] Cal. .45 (steel-jacketed) ball projectile - 230 grains.

[2] Cal. .22 fragment-simulating projectile - 17 grains.

Table II

Physical Properties of Fiberglas Samples as Reported by

Owens-Corning Fiberglas Corporation

Fabric #	Weight ozs. Sq. yd.	Thickness Inches MM	Ends per Inch	Picks per Inch	Weave	Warp Yarn	Fill Yarn	Break. Str. Lbs./" Warp	Break. Str. Lbs./" Fill
ECC-112	2.3	.003	40	39	Plain	450-1/2-5 TPI	450-1/2-5 TPI	110	105
ECC-115	2.5	.004	48	48	"	225-1/0-1½ TPI	225-1/0-1½ TPI	115	120
ECC-116	3.4	.004	60	58	"	450-1/2-5 TPI	450-1/2-5 TPI	160	145
ECC-117	3.[illegible]	.004	64	62	"	225-1/0-1½ TPI	225-1/0-1½ TPI	140	140
ECC-127	6.4	.007	42	32	"	450-3/2-5 TPI	450-3/2-5 TPI	380	300
ECC-128	6.2	.007	42	32	"	225-1/3-5 TPI	225-1/3-5 TPI	325	250
ECC-138	7.0	.008	64	60	crow	450-2/2-5 TPI	450-2/2-5 TPI	375	330
ECC-1[illegible]1	14.1	.015	28	16	Plain	450-4/5-5 TPI	450-4/5-5 TPI	700	460
ECC-162	12.0	.015	28	16	"	225-2/5-5 TPI	225-2/5-5 TPI	675	420
X-1549	17.2	.020	[illegible]1	18	"	225-4/4-5 TPI	225-4/4-5 TPI	770	760
X-1581	5.3	.007	39	34	"	225-1/3-5 TPI	225-1/3-5 TPI	280	250

Table III

Correlation Between Resistance to Perforation of Fiberglas Samples

and Their Yarn and Texture Characteristics

Ballistic Limit (F/S)	Sample	Ends Per Inch	Yarn
Cal. .45 (steel-jacketed) Ball Projectiles:			
549	X-1581	39	225 - 1/3 - 5 T. P. I.
588	ECC-115	48	225 - 1/0 - 1½ T. P. I.
593	ECC-128	42	225 - 1/3 - 5 T. P. I.
618	ECC-162	28	225 - 2/5 - 5 T. P. I.
647	ECC-127	42	450 - 3/2 - 5 T. P. I.
6[illegible]9	X-1549	21	225 - 4/4 - 5 T. P. I.
671	ECC-117	64	225 - 1/0 - 1½ T. P. I.
698	ECC-112	40	450 - 1/2 - 5 T. P. I.
698	ECC-116	60	450 - 1/2 - 5 T. P. I.
732	ECC-161	28	450 - 4/5 - 5 T. P. I.
738	ECC-138	64	450 - 2/2 - 5 T. P. I.
Cal. .22 Fragment-Simulating Projectile:			
956	ECC-162	28	225 - 2/5 - 5 T. P. I.
974	ECC-117	64	225 - 1/0 - 1½ T. P. I.
988	X-1581	39	225 - 1/3 - 5 T. P. I.
1022	X-1549	21	225 - 4/4 - 5 T. P. I.
1030	ECC-115	48	225 - 1/0 - 1½ T. P. I.
1036	ECC-112	40	450 - 1/2 - 5 T. P. I.
1062	ECC-116	60	450 - 1/2 - 5 T. P. I.
1082	ECC-127	42	450 - 3/2 - 5 T. P. I.
1090	ECC-128	42	225 - 1/3 - 5 T. P. I.
1108	ECC-138	64	450 - 2/2 - 5 T. P. I.
1183	ECC-161	28	450 - 4/5 - 5 T. P. I.

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ABSTRACT:

Samples of fiber-glase varying in weave, texture and weight were tested for resistance to perforation by cal 0.22 fragment-simulating, and 0.45 cal steel -jacketed ball projectiles. The resistance of these samples to perforation seems to reflect the characteristics of the yarn and the closeness of their texture, since those showing greatest reeistance were closely woven and made of fine-fibred, Multi-stranded, high-twist yarn while those affording loweet resistance were less closely woven and made of yarns with coarser fibres and lower number of strands. The best sample to perforation resistance by cal. 0.45 bullets compares favorably with that of an equivalent weight of $17\frac{1}{2}$ oz nylon duck, but under impact of the 0.22 cal projectile it was considerably inferior, however, the resistance of Hadfield manganese eteel of equal weight is much greater than either of these fabrics.

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